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AUTOMATED VHF FREQUENCY ASSIGNMENT SYSTEM (FAS) FOR FAA AIR TRA--ETC(U)

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SUPPLEMENT 1

AUTOMATED VHF FREQUENCY ASSIGNMENT SYSTEM (FAS) FOR FAA AIR TRAFFIC CONTROL COMMUNICATIONS. Supplement 1.

IIT Research Institute
Under Contract to
DEPARTMENT OF DEFENSE
Electromagnetic Compatibility Analysis Center
Annapolis, Maryland 21402

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16. Abstract

An automated Frequency Assignment System (FAS) was developed as a means of providing frequency assignment plans for FAA Air Traffic Control (ATC) VHF communications facilities. The FAS consists of a series of computer models described in FAA-RD-76-14. The system can be used for assignment gaming including partial and complete assignments, detecting violators, statistical analyses, and plots of service volume.

This report describes improvements made to the FAS during 1977 and supplements FAA-RD-76-14.

17. Key Words

AIR TRAFFIC CONTROL
FREQUENCY MANAGEMENT
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INTERFERENCE
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PREFACE

The Electromagnetic Compatibility Analysis Center (ECAC) is a Department of Defense facility, established to provide advice and assistance on electromagnetic compatibility matters to the Secretary of Defense, the Joint Chiefs of Staff, the military departments and other DoD components. The center, located at North Severn, Annapolis, Maryland 21402, is under policy control of the Assistant Secretary of Defense for Communication, Command, Control, and Intelligence and the Chairman, Joint Chiefs of Staff, or their designees, who jointly provide policy guidance, assign projects, and establish priorities. ECAC functions under the executive direction of the Secretary of the Air Force and the management and technical direction of the Center are provided by military and civil service personnel. The technical operations function is provided through an Air Force sponsored contract with the IIT Research Institute (IITRI).

This report was prepared for the Systems Research and Development Service of the Federal Aviation Administration in accordance with Interagency Agreement DOT-FA70WAI-175, as part of AF Project 649E under Contract F-19628-78-C-0006, by the staff of the IIT Research Institute at the Department of Defense Electromagnetic Compatibility Analysis Center.

To the extent possible, all abbreviations and symbols used in this report are taken from American Standards Y10.19 (1967) "Units Used in Electrical Science and Electrical Engineering" issued by the USA Standards Institute.

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ENGLISH/METRIC CONVERSION FACTORS

LENGTH

From \ To	cm	m	km	in	ft	mi	nmi
cm	1	0.01	1×10^{-5}	0.3937	0.0328	6.21×10^{-6}	5.39×10^{-6}
m	100	1	0.001	39.37	3.281	0.0006	0.0005
km	100,000	1000	1	39370	3281	0.6214	0.5395
in	2.540	0.0254	2.54×10^{-5}	1	0.0833	1.58×10^{-5}	1.37×10^{-5}
ft	30.48	0.3048	3.05×10^{-4}	12	1	1.89×10^{-4}	1.64×10^{-4}
mi	160,900	1609	1.609	63360	5280	1	0.8688
nmi	185,200	1852	1.852	72930	6076	1.151	1

AREA

From \ To	cm^2	m^2	km^2	in^2	ft^2	mi^2	nmi^2
cm^2	1	0.0001	1×10^{-10}	0.1550	0.0011	3.86×10^{-11}	5.11×10^{-11}
m^2	10,000	1	1×10^{-6}	1550	10.76	3.86×10^{-7}	5.11×10^{-7}
km^2	1×10^{10}	1×10^{6}	1	1.55×10^{9}	1.08×10^{7}	0.3861	0.2914
in^2	6.452	0.0006	6.45×10^{-10}	1	0.0069	2.49×10^{-10}	1.88×10^{-10}
ft^2	929.0	0.0929	9.29×10^{-8}	144	1	3.59×10^{-8}	2.71×10^{-8}
mi^2	2.59×10^{10}	2.59×10^{6}	2.590	4.01×10^{9}	2.79×10^{7}	1	0.7548
nmi^2	3.43×10^{10}	3.43×10^{6}	3.432	5.31×10^{9}	3.70×10^{7}	1.325	1

VOLUME

From \ To	cm^3	liter	m^3	in^3	ft^3	yd^3	fl. oz.	fl. pt.	fl. qt.	gal.
cm^3	1	0.001	1×10^{-6}	0.0610	3.53×10^{-5}	1.31×10^{-6}	0.0338	0.0021	0.0010	0.0002
liter	1000	1	0.001	61.02	0.0353	0.0013	33.81	2.113	1.057	0.2642
m^3	1×10^{6}	1000	1	61,000	35.31	1.308	33,800	2113	1057	264.2
in^3	16.39	0.0163	1.64×10^{-5}	1	0.0006	2.14×10^{-5}	0.5541	0.0346	2113	0.0043
ft^3	28,300	28.32	0.0283	1728	1	0.0370	957.5	59.84	0.0173	7.481
yd^3	765,000	764.5	0.7646	46700	27	1	25900	1616	807.9	202.0
fl. oz.	29.57	0.2957	2.96×10^{-5}	1.805	0.0010	3.87×10^{-5}	1	0.0625	0.0312	0.0078
fl. pt.	473.2	0.4732	0.0005	28.88	0.0167	0.0006	16	1	0.5000	0.1250
fl. qt.	948.4	0.9463	0.0009	57.75	0.0334	0.0012	32	2	1	0.2500
gal.	3785	3.785	0.0038	231.0	0.1337	0.0050	128	8	4	1

MASS

From \ To	g	kg	oz	lb	ton
g	1	0.001	0.0353	0.0022	1.10×10^{-6}
kg	1000	1	35.27	2.205	0.0011
oz	28.35	0.0283	1	0.0625	3.12×10^{-5}
lb	453.6	0.4536	16	1	0.0005
ton	907,000	907.2	32,000	2000	1

TEMPERATURE

$°F = 5/9\ (°C - 32)$

$°C = 9.5\ (°F) + 32$

FEDERAL AVIATION ADMINISTRATION
SYSTEMS RESEARCH AND DEVELOPMENT SERVICE
SPECTRUM MANAGEMENT STAFF

STATEMENT OF MISSION

The mission of the Spectrum Management Staff is to assist the Department of State, Office of Telecommunications Policy, and the Federal Communications Commission in assuring the FAA's and the nation's aviation interests with sufficient protected electromagnetic telecommunications resources throughout the world to provide for the safe conduct of aeronautical flight by fostering effective and efficient use of a natural resource--the electromagnetic radio-frequency spectrum.

This objective is achieved through the following services:

- Planning and defending the acquisition and retention of sufficient radio-frequency spectrum to support the aeronautical interests of the nation, at home and abroad, and spectrum standardization for the world's aviation community.

- Providing research, analysis, engineering, and evaluation in the development of spectrum related policy, planning, standards, criteria, measurement equipment, and measurement techniques.

- Conducting electromagnetic compatibility analyses to determine intra/inter-system viability and design parameters, to assure certification of adequate spectrum to support system operational use and projected growth patterns, to defend the aeronautical services spectrum from encroachment by others, and to provide for the efficient use of the aeronautical spectrum.

- Developing automated frequency-selection computer programs/routines to provide frequency planning, frequency assignment, and spectrum analysis capabilities in the spectrum supporting the National Airspace System.

- Providing spectrum management consultation, assistance, and guidance to all aviation interests, users, and providers of equipment and services, both national and international.

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SECTION 1

INTRODUCTION

BACKGROUND

The growth of aircraft traffic in the United States is placing unprecedented demands on Federal Aviation Administration (FAA) air traffic control (ATC) facilities. The FAA frequency managers are finding it increasingly difficult, within the spectrum resources available, to provide frequency assignment plans compatible with the rapidly growing ATC operational requirements.

Earlier reports[1,2] described an automated Frequency Assignment System (FAS) developed by the Electromagnetic Compatibility Analysis Center (ECAC). The FAA had requested ECAC to develop a means of rapidly evaluating the relative merits of alternate courses of action to meet the growing ATC communications requirements.

The FAS design incorporates two basic program modules. The first module is used to build an intersite constraint matrix that designates the channel separation necessary to maintain a specified protection criterion (desired-to-undesired signal ratio [D/U]) between the ATC requirements. Each ATC requirement is defined by its associated ATC function and geographical site/service volume information.

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[1]Beall, L. et al., *An Automated FAA Air Traffic Control Frequency Assignment Model*, FAA-RD-73-184, ECAC, Annapolis, MD, December 1973.

[2]Hensler, T., *Automated VHF Frequency Assignment System (FAS) for FAA Air Traffic Control Communications*, FAA-RD-76-14, Annapolis, MD, February 1976.

The second module generates the frequency assignments by using the channel-separation matrix and a data file. This file contains frequencies denied at each ATC site because of cosite requirements, such as intermodulation and adjacent-channel constraints. As assignments are made, the Cosite File is appropriately updated. Because the order in which assignments are made can affect the total assignment efficiency, i.e., number of discrete channels required, a means was developed by which the FAS orders requirements according to certain congestion criteria before the assignment is made.

A data base for the FAS was obtained by collecting and verifying data that describes the requirements for FAA air traffic control. This task also included designing and programming a retrieval and maintenance system for the data base.

This report is a supplement to Reference 2 and describes improvements made to the Frequency Assignment System during 1977.

OBJECTIVE

The objectives of this task were to develop a new assignment model that considers cosite and intersite constraints in determining the assignment order and to make program modifications to existing FAS models for the purpose of reducing system response time by increasing the efficiency of computer usage.

APPROACH

The FAS improvement effort commenced with the development of a new assignment model that considers both cosite and intersite con-

straints in determining the assignment order. The assignment order is modified after each requirement is assigned a frequency so that the most constrained requirement is the next candidate in the assignment process.

The FAS was further enhanced by developing a new intersite constraint matrix generator. This new generator calculates the matrix as a series of blocks or submatrices rather than row by row.

The Cosite File generator was also modified. The modification enables the new assignment model to quickly process Cosite File records and provides a sizable reduction in Cosite File storage space.

SECTION 2

FREQUENCY ASSIGNMENT SYSTEM IMPROVEMENTS

GENERAL DESCRIPTION

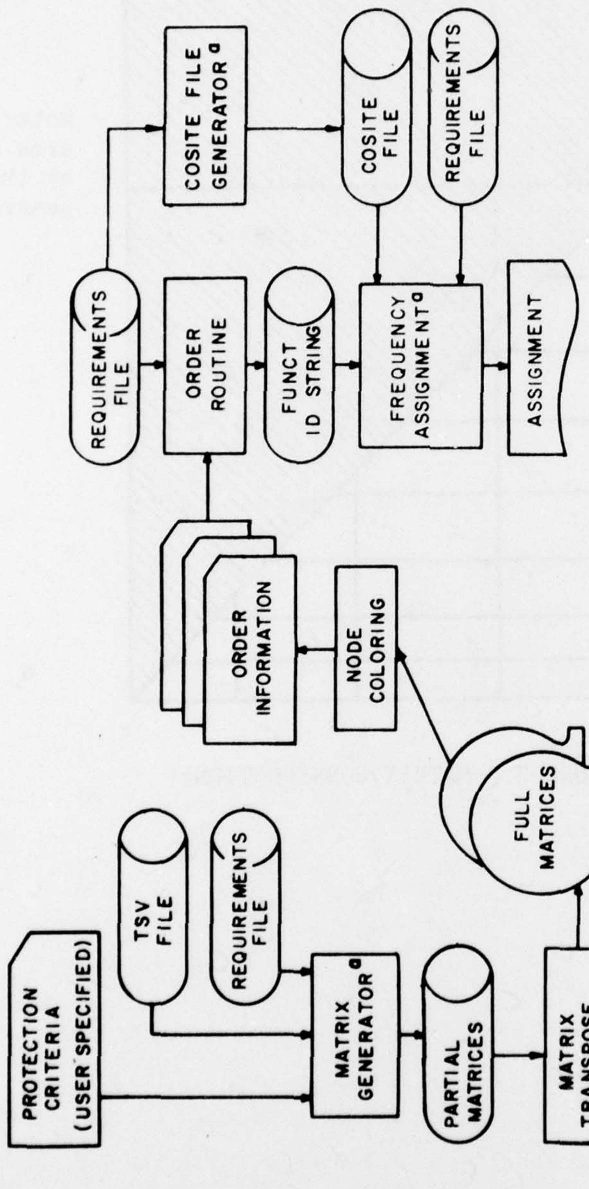
The FAS achieves a compatible frequency assignment by first generating an intersite constraint matrix to designate the cochannel and adjacent-channel assignment constraints imposed on each requirement needing an assignment.

The second step requires the development of a Cosite File that represents the cosite constraints imposed on the assignment. The third step is the frequency assignment process which uses the results of steps one and two, the intersite constraints, and the cosite constraints.

The improvements made to the FAS affect all three steps described above. FIGURE 1 is a flow diagram for the FAS.

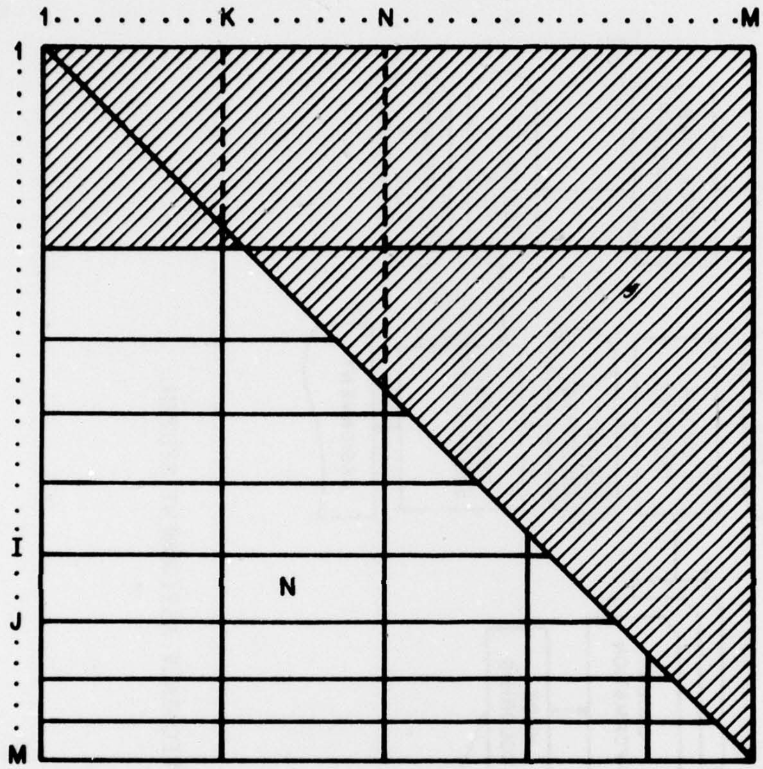
MATRIX GENERATOR PROGRAM

The new Matrix Generator Program performs the same basic calculations as the old version. The main difference is in the construction of the matrix. The old version calculated the matrix one row at a time. The new matrix generator uses the technique of calculating submatrices or blocks. FIGURE 2 shows typical blocks that would be calculated and their order of calculation. Thus, requirements I through J and K through N would be in the computer memory at the same time in order to calculate all the elements in block N. This new technique is more efficient than the method used in the earlier version.



[a]Models updated during 1977.

FIGURE 1. FREQUENCY ASSIGNMENT SYSTEM.



Note: Shaded area not calculated by the matrix generator.

FIGURE 2. MATRIX CONSTRUCTION.

COSITE FILE

A Cosite File must be constructed preparatory to the generation of a frequency assignment plan. This file accounts for the intra-site or cosite constraints for each site to be assigned a frequency. Included in this file are frequencies of FM radio broadcasting and television stations plus administrative and emergency frequencies. All ATC assignments considered as fixed (not to be reassigned by the FAS) are reflected in this file along with any 2-signal (and optional 3-signal) third-order intermodulation products caused by these fixed assignments. This ensures protection of existing assignments as additional requirements are assigned at a given site. The assignment model updates the Cosite File as each assignment is made so that the file is always current.

The format of the Cosite File was modified. The purpose of the modification was to save computer storage and decrease computer processing time, thus reducing system response time. Each record in the old format contained a list of all channel numbers denied at each site and the numbers ranged from 1 (135.975 MHz) to 720 (118.000 MHz). The new format uses an array of 720 bits that are set at either one or zero to denote denied or not-denied channels, respectively. This bit array is also advantageous when used with the new assignment model discussed in the next section.

FREQUENCY ASSIGNMENT

The assignment phase of the FAS can use one of four models.

1. Site Exhaustive Model
2. Frequency Exhaustive Model

3. Reassignment Analysis Model (RAM)
4. Dynamic Ordering Model

The first three models, as discussed in Reference 2, determine the next requirement to be assigned on the basis of a predetermined assignment sequence. This order is generated using the constraints imposed by the intersite channel-separation matrix. For the Dynamic Ordering Model developed during 1977, the assignment sequence develops as assignments are made based on both the cosite *and* intersite constraints. The next requirement to be assigned a frequency is determined by examining each unassigned requirement to find the one most constrained (fewest channels available for assignment). This method of dynamic ordering and consideration of the cosite *and* intersite constraints to determine the order should result in better spectrum utilization.

FIGURE 3 is a flowchart of the Dynamic Ordering Model. The model builds a denied-channel array for all requirements needing a frequency. The array is constructed using the intersite matrix and Cosite File. Each requirement will have frequencies denied because of pre-assigned ATC requirements (military, Canadian, Mexican) and existing cosite constraints.

Once the initial constraints are entered into the denied-channel array, the array is searched to find the most constrained requirement, i.e., the one with the fewest channels available for assignment. The first available frequency (the one closest to the starting frequency in the band) is assigned to this requirement and the denied-channel array is updated.

This update reflects both the intersite and cosite constraints that result from the new assignment. The array is then searched to

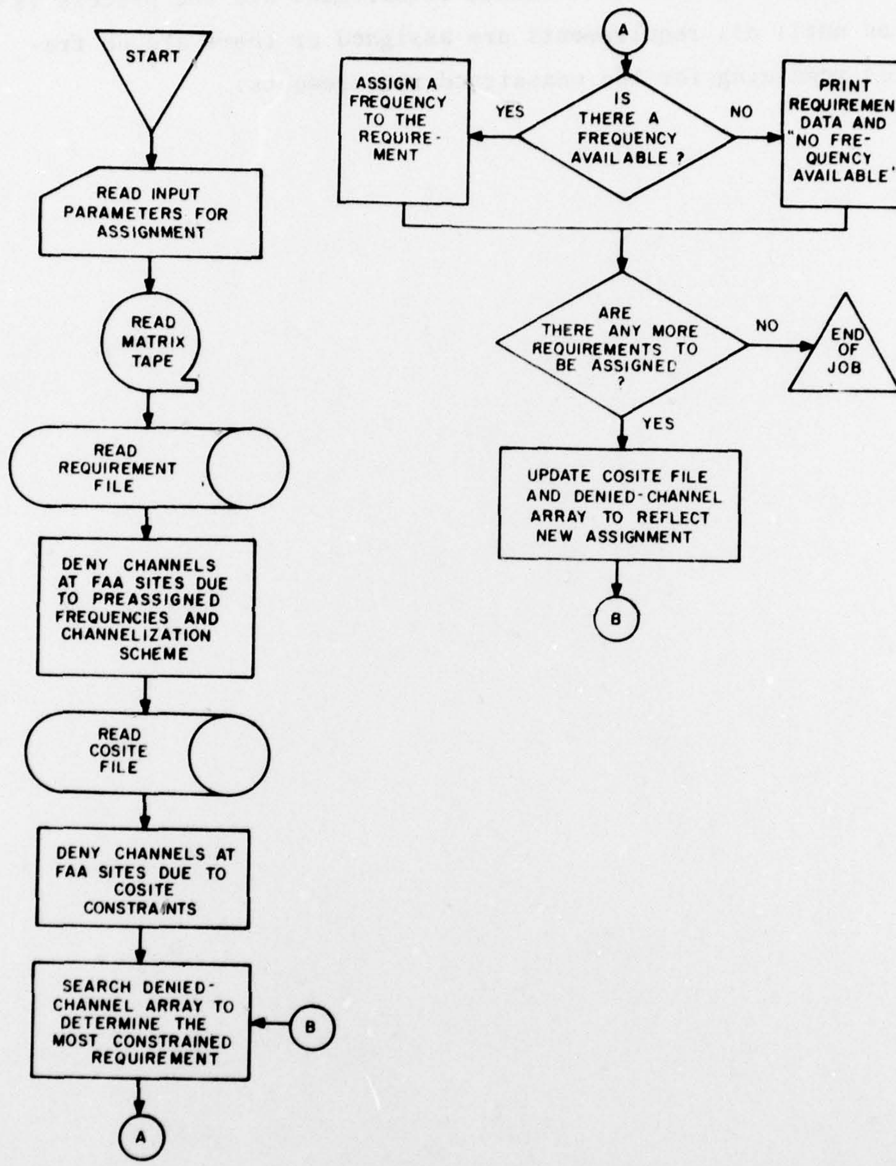


FIGURE 3. FLOWCHART OF THE DYNAMIC ORDERING ASSIGNMENT MODEL.

find the remaining most-constrained requirement and the process is repeated until all requirements are assigned or there are no frequencies remaining for the unassigned requirements.

SECTION 3

RESULTS

During 1977, the FAS was enhanced through improvements to the cosite model, redesign of the intersite matrix generator, and the development of a new assignment model. Although the basic design of the FAS is the same, these recent developments have improved the efficiency, flexibility, and responsiveness of the assignment process. The design of the FAS permits frequency managers to evaluate potential solutions to assignment problems including the ability to:

1. Generate channel assignments for existing or proposed FAA VHF ground communications requirements at ATC facilities.
2. Produce frequency assignments in a manner that attempts to make efficient use of the available spectrum resources by assigning the ATC requirements in an order that starts with the most difficult and progresses to the least difficult to assign, while taking into consideration both cosite and intersite constraints.
3. Make frequency-assignment plans that conform to the technical and operational constraints specified by the user.